

Mapping of the mountain taiga geosystems of the Baikal Natural Territory

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Abstract. Results from investigating the geosystems of Baikal Natural Territory in its western part (Primorskii Range) are presented. For studying macroslope of these mountain range (having an easterly aspect for the Primorskii Range), the regional background and the main factors of the landscape differentiation of the study areas were analysed. Structural features of topological geosystems are revealed, and large-scale maps of key areas are compiled (at a scale of 1:50 000). Maps of the landscape-typological structure were created on the basis of the structural-dynamic and facies analysis of landscapes. Based on of V. B. Sochava's theory of geosystems it is meant for use in processing and ordering a large body of information. It is established that the main factors influencing the landscape diversity are the aspect and steepness of the slopes, the composition and structure of rocks, the absolute height, the amount of atmospheric precipitation, and anthropogenic impacts. It is determined that the influence of the lithomorphic factor is widespread throughout the study areas, the hydromorphic factor is also important, the cryomorphic factor occurs additionally in the goletz zone.

1. Introduction

The world geographical and ecological literature discusses the issue related to changes in intensity and directedness of many natural processes caused by global and regional climatic shifts as well as by anthropogenic impacts. These processes alter the longstanding functioning of geosystems, their long-term dynamics and eventually the evolution of landscapes. The changes encompass significant areas (thawing of permafrost and northward retreat of the permafrost boundary, desertification of territories, encroachment of forest upon the tundra, etc.). But they also have a local and regional character: the natural characteristics of particular territories leave their imprint on the formation and dynamics of geosystems. As the model region, we used the Baikal natural territory with its mountain-taiga, goletz, subgoletz, mountain-steppe, mountain-depression and aquatic geosystems. Climate warming and humidification has been recorded in recent years, a complex fire-hazardous situation has been emerging, and tourism has been developed intensely. Expedition-based investigations made in the summer seasons of 2012-2018 years sought to determine the spatial regularities in the distribution of geosystems of the topological rank. In accordance with the objective set, we analyzed the regional background and the main factors for the landscape differentiation in the study areas. The analysis revealed the regularities in the structure of geosystems of the topological level, and landscape maps of the key areas were compiled at a large scales of 1:100 000 and 1:50 000.



2. Objects, data and methods

The landscape structure was studied in the key areas of Primorskii Range; the former includes the eastern macroslope of Primorskii Range from Maloe More along the Laninskii brook to the Sarminskii goletz. On the investigated territory of the Primorskii Range, the Sarma bare mountain with the peak of 1658 m rises. The top of the char is composed of proterozoic intrusive rocks of granite-gneiss, shales and coarse-clastic material covered with epiphytic lichens. The precipitation here is from 400 mm to 1000 mm on top of the Range.

Field description in areas 10x10 and 20x20 m in size were carried out by using the techniques developed and tested in landscape investigations [1]. A total of more than 200 areas were documented.

The total area of the study is 120 square kilometers at 1:100 000 scale [2]. The area of the transect of scale 1:50 000 in figure 1 is 30 square kilometers.

To study the current status of the landscapes used the geosystem regional-typological approach of the Siberian geographical school tested in different regions of Siberia [3].

The regional-typological approach forms an important part of V. B. Sochava's theory of geosystems [4] and is meant for use in processing and ordering a large body of information. Therefore, it has gained widespread acceptance in regional geographical research, in landscape mapping, and in other kinds of thematic mapping. When studying and mapping a territory with varied and complicated natural and socio-economic conditions, due regard must be had to the regional and local, individual and typical features of geosystems, the properties of their homogeneity and heterogeneity, and to the chorological and typological aspects of generalization [5]. It is worthwhile making such investigations within the landscape framework using the regional-typological approach where the description of local geosystems is performed in a regional setting with consideration for their generic (typical) and unique (individual) peculiarities. Presentation of elementary geosystems in the structure of hierarchically larger subdivisions of natural environment furnishes a means of assessing their properties with regard to the regional specificity of the landscape sphere. To accomplish this, use is made of the principle of two-row classification of geosystems, identifying geomers and geochores, and homogeneous and heterogeneous spatial systems.

Landscape maps of the key areas at the topological level were compiled in terms of the graphical model of the hierarchy of geosystems for the entire Baikal region [6]. A physical-geographical regionalization has been carried out according to the individual attributes to Legend 1. A mapping of the landscapes was carried out according to the typological attribute by displaying geosystems of topological dimension at the level of groups of facies and separated facies.

The basis for landscape mapping was provided by remote sensing data from Landsat-5 TM, Landsat-7 ETM+, Landsat-8 OLI (resolution of 30 and 15 m, respectively), GeoEye (2.44 m), Kanopus-V (10.5 m), Resource P-1 (Sangur-U scanner, 2 - 0.7 m), STRM 4.1 for creating digital terrain models (in gradation angles for mountainous areas including steep slopes). Field database includes more than 200 points of description for each study area where the structure of landscape units was determined, their boundaries were delineated, and the map legend was updated. Published and archival material, topographic maps and various thematic maps were also used.

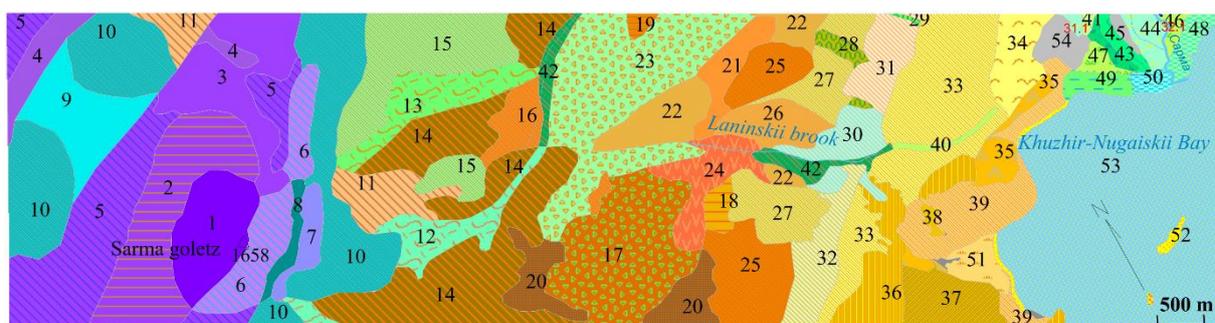


Figure 1. Map of geosystems of Primorskii Range. For 1–54, see legend 1.

2.1. Legend 1 to the 1:50 000 map of geosystems of Primorskii Range.

Goletz mountain-tundra geosystems of Primorskii Range on Lower-Proterozoic quartzites, and shale at 1500–1650 m, with physical weathering by cryogenic processes and nivation 1. Of flattened summits, mountain-tundra detrital lichen on bedrocks (s). 2. Near-the-top lichen with sparse groups of dwarf Siberian pine (pp). 3. Of hilly summits, mountain-tundra lichen, on scattered small-boulders and with sparse dwarf Siberian pine (p). 4. Of gentle slopes, mountain-tundra lichen (pp). 5. Slope mountain-tundra subshrub-moss dwarf Siberian pine (s). 6. Of the nival bench, dwarf Siberian pine bilberries-crowberries with juniper, on detrital coarse-skeletal soils (sf). Subgoletz shrub and sparse-forest on shale, plagiogneisses and amphibolites, at 1350–1500 m, colluvial screes and coarse-skeletal podzols, dominated by cryogenic processes 7. Dwarf Siberian pine with dwarf birch, juniper, rowan bilberries-great bilberries (pp). 8. Meadow nival niches with water-filled troughs (sf). 9. Dwarf Siberian pine saddles, bilberries-cowberries, with oppressed young Siberian stone pine trees (pp). 10. Dwarf Siberian pine and yernik moss-lichen on scattered rocks (sf). Mountain-taiga geosystems of reduced development at 1200–1350 m 11. Of gentle slopes, sparse-forest Siberian stone pine small grass-lichen, with groups of dwarf Siberian pine, on coarse-skeletal mountain soils (s). 12. Siberian stone pine-spruce subshrub-sedge-sphagnum on peaty-humous soils (s). 13 Larch-birch with spruce in underwood, Duschekia/horse-tail on soddy acid soils (v). *Mountain-taiga geosystems of limited development at 900–1200 m.* 14. Larch with Siberian stone pine, ledum, with underwood of alder and rowan, with juniper, on forest coarse-humous soils (pp). 15. Birch bilberries-great bilberries with young Siberian stone pine on podzolic soils (s). 16. Siberian stone pine bilberries-great bilberries with alder, rowan and juniper on soddy-podzolic soils (p). 17. Larch with birch on screes, on thin podzolized soils (p). 18. Larch-Siberian stone pine subshrub-true moss on peaty-coarse skeletal soils (pp). 19. Larch bilberries-ledum moss on soddy soils (pp). 20. Siberian stone pine-larch cowberries-small grass-moss with rowan on humous soils (ppe). 21. Siberian stone pine subshrub with rock remnants and screes (ppe, s). 22. Larch bilberries-ledum-sphagnum on peaty-humous soils (p). 23. Larch-birch on humous-gley pyrogenic soils (s). 24. Siberian stone pine-spruce in topographic lows horse-tail/small grass-moss on illuvial humous soils (s). 25. Larch with birch grass-true moss, with underwood of Duschekia and rowan, on grey thin soils (pp). 26. Larch with pine bilberries-ledum, on weakly podzolized soils (pp). 27. Larch grass with birch, aspen and alder in underwood, on pyrogenic podzolic (s). 28. Larch with spruce small grass-true moss, on humous-gley soils (sf). 29. Of drainage lows, larch-Siberian stone pine sedge-moss, on illuvial humous soils (pp). *Mountain-steppe geosystems of the Western Transbaikalian type on gravelites and conglomerates at 600–900 m.* 30. Slope mountain-steppe forb-grass (s). 31. Thyme-Leymus slope on stony thin soils (me, sf). 32. Wormwood-grass slope with Caragana on thin petrozems (me, sf). 33. Thyme-Leymus and wormwood-fescue on petrozems (sf). 34. Meadow-grass and feather-grass/wheatgrass on chestnut soils (p). *Submontane subtaiga light-coniferous xerophytic geosystems on eluvial sands and deluvial loams at 500–600 m.* 35. Sparse larch summit rhododendron-grass on petrozems (s). 36. Sparse larch slope sedge-grass on petrozems (s). 37. Near-the-top larch grass with hard rock remnants (s). 38. Slope larch shrub-grass on petrozems (pp). 39. Open woodland, larch grass on slopes disturbed by recreational activity (a). *Valley meadow and bog geosystems on Quaternary alluvial and deluvial slope deposits* 40. Floodplain willow-shrub forb-meadow on soddy soils (sl). 41. Slope willow-shrub forb on alluvial soddy soils (s). 42. Spruce-larch with willow, sedge-grass-moss on alluvial soils. 43. Sedge-forb on peat soils (sf). 44. Forb-grass on alluvial meadow soils (s). 45. Meadow sedge-grass waterlogged (sf). 46. Sedge-small grass on alluvial meadow-boggy soils (sf). 47. Boggy floodplain sedge (sf). 48. Subshrub-grass with pools on peat-bog soils (sf). 49. Sedge-small grass-sphagnum on peat soils (sf). 50. Sedge-small grass near mouths (s). Coastal inclined plains and subaquatic geosystems on modern alluvial deposits 51. Coastal meadow-steppe grass-forb on eroded meadow soils (sl, a). 52. Sedge-small grass on outwash sandy-pebble alluvium (s). 53. Shallow hydrophytic coastal and bottom pebble-sandy (s). Anthropogenic geosystems 54. Residential (a). Dynamical categories of groups of facies: p – primary stablest, pp – pseudo-primary, s – serial, ppe – pseudo-primary extra-regional, sf – serial factorial, sl – stably long-lasting secondary, a – anthropogenically transformed.

3. Results and discussion

The study area in Priol'khonie encompasses the southeastern (facing Baikal) macroslope of Primorskii Range. The topography of the slope is complicated by an extended bench (Obruchev fault) with a height difference of up to 1000 m. Archean and Lower Proterozoic rocks include granites, diorites, quartzites, shale and gneisses. Below the bench, an inclined peneplain of the Priol'khonskoe plateau stretches, which is composed of gneisses, amphibolites and quartzites of the Chernorud Archean formation, with the mantle of Mid- and Upper-Quaternary eluvial sands and deluvial loams. The climate of the territory is distinguished by winters with little snowfall, the anticyclonic winter regime with insufficient atmospheric humidification (100–400 mm), and by a short growing period (4–4.5 months). The mean January and July air temperatures, respectively, are -17.3 and 14.4°C , and the mean annual temperature is 0.7°C [7].

The geosystems of this key area (figure 1, legend 1) belong to the Baikal-Dzhugdzhur mountain-taiga region of the Cisbaikalian goletz-mountain-taiga and depression province. The territory covers the Primorskii goletz-mountain-taiga and Ol'khonskii mountain-subtaiga and submontane-steppe physical-geographical districts [8]. The specific character of the altitudinal-belt landscape structure including an almost entire set of geosystems of the mountains surrounding Baikal is governed by the manifestation of the barrier-shadow, arid-depression and submontane effects complicated by the influence of Baikal's water mass [9]. As a result, there emerges a combination of contrasting (in natural conditions) landscapes united into the Anga-Sarma middle-mountain taiga, largely light-coniferous area and the Olkhon mountain-subtaiga and submontane-steppe area. Noteworthy among the main exogenous processes are frost weathering, rill and sheet wash, linear erosion, cryogenic processes on talus aprons, karst and suffosion in topographic lows [10]. Coastal landscapes are actively used for recreation and undergo a significant anthropogenic load. The study territory is dominated by the Sarma goletz with its summit at 1658 m. This is composed of Proterozoic intrusive rocks, namely, granitogneisses, shale and coarse detritus covered by epiphytic lichens. The atmospheric precipitation amount is 400–500 mm. The facies of the goletz planation surface are represented by mountain-tundra lichen geosystems (1-2, see numbers at figure 1 and in the legend 1) dominated by *Cladonia rangiferina*, *Tephroseria porphyrantha* and *Gasparrinia elegans* of the cryomorphic-lithomorphic series. Under the influence of cryogenic and erosion processes there occur scattered granitogneiss small-boulders, small spot medallions of frost heaving of detrital earth materials. The gentle goletz (4) slopes are occupied by shrub groups of *Pinus pumila*, *Betula rotundifolia*, *Betula nana* and singly occurring *Juniperus communis*. The steep slopes have the eastward and south-eastward aspect (5). The upper part of the slopes is home for nival processes at snow patches (6); the middle and lower parts (7) include the subgoletz belt of closed dwarf Siberian pine with *B. rotundifolia* on coarse-skeletal soils. The massif of the shrub belt is sparse because of a presence of lichen waste areas with stone runs. The lows show outcrops of groundwater, with small subalpine meadows of the forb/horse-tail series (8). The upper part of the mountain-taiga belt (14-29) is represented by a sparse subshrub-moss-lichen Siberian stone pine forest with groups of dwarf Siberian pine on a thin layer of podzols, often with outcrops of rocks with an imprint of cryogenic processes. The middle mountains are occupied by larch-Siberian stone pine subshrub-true moss forests.

On flattened watershed divides there occur screes consolidated by vegetation of larch and birch trees as well as weakly consolidated, sometimes with groups of dwarf Siberian pine. Hard-rock ridges are seen to include low rock remnants. The precipitation amount here is smaller, 300–400 mm. The lower part of the mountain-taiga belt (30-34) is the transition zone to the steep slopes of Primorskii Range. The great bilberries-ledum forests with pine are replaced by mixed aspen-birch-pine shrub-grass, Spiraea-grass (with *Duschekia fruticosa* and *Sorbus sibirica*) forests and birch-larch grass-true moss (often pyrogenically disturbed) forests. Pine forb forests with underwood of *Rhododendron dauricum* are observed on the southern slopes of moderate steepness. There occur soddy-podzolic, soddy-weakly podzolized soils. The degree of pyrogenic disturbance caused by frequent ground fires is high. The first signs of steppization emerge here. The lower part of the slopes, from the border o

forest down the slope, includes forb meadow steppes, followed by mountain dry petrophytic steppes. The steepness of the slopes of the mountain range reaches 40–45° (32), and erosion-gravitational processes are taking place. Thyme-Leymus, wormwood-steppes on the slopes reside on thin layers of coarse-skeletal soils. There occur *Caragana pygmaea* and *Cotoneaster melanocarpus*. Sparse larch trees emerge nearer to the foot of the slopes. The submontane subtaiga landscapes along the foot of the mountain range are represented by dry sparse larch ledum grass and pine shrub forb forests which, nearer to Baikal, are replaced by sparse larch forests. This area is characterized by minimal precipitation amounts, 200–300 mm. The deeply incised valley (42) of the Laninskii brook in Primorskii Range, and also the depressions with ouvals and balkas have a V-shaped profile where there is an enhanced contribution from small-leaved species and communities of different species of willows: *Salix jensiseensis*, *S. hastate* and others, and in places from *Populus tremula*. Along the narrow gullies of the streams there occur groups of shrubs with willows, in places with larch trees. The geosystems of the second key area on Barguzin Range also belong to the Baikal-Dzhugdzhur mountain-taiga region, Cisbaikalian goletz-mountain-taiga and depression province, and to the Barguzin high-mountain/goletz and Middle Baikal mountain-Taiga and subtaiga-depression districts. The trail along which the investigations

4. Conclusions

The landscape regularities underlying the classification of geosystems and used for the map legends were revealed in large-scale mapping of the key areas. Regional characteristics of the position of facies and their groups were identified in the system of dynamical categories. The landscape diversity of the mountain territories used in this study is associated primarily with the influence of the lithomorphic factor, although a considerable role is played by the hydromorphic factor, the cryomorphic factor at elevations above 1500 m, and by the xeromorphic factor in Priol'khonie. The main differentiation factors for the geosystems include the exposure differences in humidification and insolation, the bedding characteristics of rocks, their fissuring and composition, the degree of stoniness of the slopes, the absolute height, the steepness of the slopes, and consolidation of the slopes by vegetation. In the process of studying the mountain geosystems of the Baikal natural territory, differences of the macroslopes facing Baikal were revealed. Primorskii Range is separated from Baikal by 9 km, the precipitation amount on the watershed divide and at the foot of the mountain range, respectively, is 400–500 and 200–300 mm, and the elevation of the watershed divide averages 1400–1600 m. Landscape structure: 1) goletz round-summit mountain-tundra lichen with screes; 2) subgoletz Siberian stone pine mountain-taiga larch-Siberian stone pine with dwarf Siberian pine, subshrub-true moss with sparse rock remnants and screes; 3) steep-slope mountain dry-steppe (Obruchev fault at 700–900 m), and 4) submontane subtaiga sparse larch forests, dry and forbs.

Acknowledgements

The work was partially supported by SB RAS (Fundamental Research Program project 17-05-00400).

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